

with application of the optimization technique when compared to the clinical treatment plans. Secondary optimization of the brainstem with the urgent sparing factor was able to increase further sparing to the brainstem by up to 9.8%, with a subtle effect on the sparing of the remaining of the structures. In addition, PTV coverage was maintained to the same degree as the delivered treatment.

**Conclusion:** The geometric optimization method allows enhancement of the existing arc geometries, resulting in significant improvements in OAR sparing, without increase to required treatment planning or delivery time.

Poster: Physics track: Treatment planning: applications

PO-0842

Non-coplanar volumetric-modulated arc therapy for craniopharyngiomas reduces doses to hippocampus

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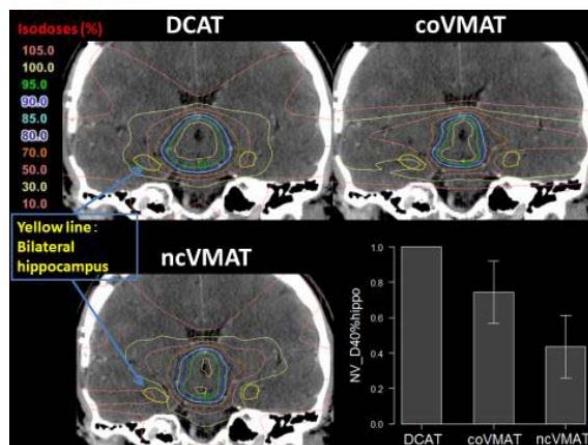
**Purpose or Objective:** As patients with craniopharyngiomas make good prognoses and as pediatric patients seem to be more sensitive to radiation than adults, irradiation of normal tissue should be minimized. Recent studies suggest that radiation-induced injuries to the hippocampus play important roles in compromising neurocognitive functioning for patients with brain tumors and it could be important to spare the hippocampus using modern planning methods for patients with craniopharyngiomas. In terms of radiation techniques, 3D conformal external beam radiotherapy delivered using dynamic conformal arc therapy (DCAT) and volumetric-modulated arc therapy (VMAT) are clinically employed to treat for patients with craniopharyngiomas. While the use of non-coplanar beams in VMAT of malignant intracranial tumors has recently been reported, no dosimetric comparison has yet been made between VMAT using non-coplanar arcs (ncVMAT) and VMAT employing only coplanar arcs (coVMAT) among patients with craniopharyngiomas. We performed a planning study comparing dose distributions to the planning target volume (PTV), hippocampus, and other organs at risk (OAR) of DCAT, coVMAT, and ncVMAT.

**Material and Methods:** DCAT, coVMAT, and ncVMAT plans were created for 10 patients with craniopharyngiomas. The prescription dose was 52.2 Gy in 29 fractions, and 99% of each PTV was covered by 90% of the prescribed dose. The maximum dose was held below 107% of the prescribed dose. CoVMAT and ncVMAT plans were formulated to satisfy the following criteria: the doses to the hippocampus were minimized, and the doses to the OAR were similar to or lower than those of DCAT.

**Results:** The mean equivalent doses in 2-Gy fractions to 40% of the volumes of the bilateral hippocampus [EQD2(40%hippos)] were 15.4/10.8/6.5 Gy for DCAT/coVMAT/ncVMAT, respectively. The EQD2(40%hippos) for ncVMAT were <7.3 Gy, which is the threshold predicting cognitive impairment, as defined by Gondi et al.. The mean doses to normal brain tissue and the conformity indices were similar for the three plans, and the homogeneity indices were significantly better for coVMAT and ncVMAT compared with DCAT.

Figure.

Coronal plans of dose distributions in a representative case and a comparison of the normalized doses covering 40% of the volume of the bilateral hippocampus using DCAT, coVMAT, and ncVMAT.



The yellow line shows the contour of the bilateral hippocampus. The normalized value of D40%hippo indicates that the dose covering 40% of the volume of the bilateral hippocampus was significantly reduced in the following order: ncVMAT, coVMAT, and DCAT (ncVMAT 0.4, coVMAT 0.7, and DCAT 1).

DCAT=dynamic conformal arc therapy, coVMAT=coplanar volumetric-modulated arc therapy, ncVMAT=non-coplanar volumetric-modulated arc therapy, NV\_D40%hippo=normalized value of D40%hippo

Table.

Summary of doses delivered to the bilateral hippocampus and the normal brain and the dose indices, in Gy.

Structure	DCAT	coVMAT	ncVMAT	P-value	P-value	P-value	P-value
Index		(Mean±SD)		(ANOVA)	(DCAT vs. coVMAT)	(DCAT vs. ncVMAT)	(coVMAT vs. ncVMAT)
Bilateral Hippo							
Maximum dose	42.3±9.8	36.2±11.2	30.5±15.0	0.121			
Mean dose	20.7±7.6	15.4±8.1	10.7±6.2	<0.05	0.515	<0.05	0.530
D40% <sub>hippo</sub>	21.7±8.4	16.2±7.6	10.3±7.9	<0.05	0.406	<0.05	0.326
EQD <sub>2</sub> (40% <sub>hippo</sub> )	15.5±7.9	10.8±6.3	6.5±6.0	<0.05	0.41	<0.05	0.51
NV_D40% <sub>hippo</sub>	1	0.7±0.2	0.4±0.2	<0.05	<0.05	<0.05	<0.05
Normal brain							
Mean dose	6.8±1.7	6.2±1.5	6.8±1.4	0.563			

If a significant difference was evident when data from the entire cohort were compared via two-way analysis of variance (ANOVA), the Bonferroni post hoc test was performed to compare pairs of modalities.

DCAT=dynamic conformal arc therapy, coVMAT=coplanar volumetric-modulated arc therapy, ncVMAT=non-coplanar volumetric-modulated arc therapy, SD= standard deviation, Hippo=hippocampus.

D40%<sub>hippo</sub>=dose to 40% of the volume of the bilateral hippocampus.

EQD<sub>2</sub>(40%<sub>hippo</sub>)=equivalent dose in 2-Gy fractions (assuming α/β=2) to 40% of volume of the bilateral hippocampus.

NV\_D40%<sub>hippo</sub>=normalized value of D40%<sub>hippo</sub> (the DCAT value was set to unity). The normalized values for coVMAT and ncVMAT were calculated as D40%<sub>hippo</sub>(coVMAT)/D40%<sub>hippo</sub>(DCAT) and D40%<sub>hippo</sub>(ncVMAT)/D40%<sub>hippo</sub>(DCAT), respectively.

**Conclusion:** ncVMAT is more appropriate than DCAT and coVMAT for patients with craniopharyngiomas. ncVMAT significantly reduces radiation doses to the bilateral hippocampus (to 50% that of the DCAT) without increasing the doses to normal brain tissue and other OAR.

PO-0843

Dosimetric evaluation of 10 years of treatment planning improvements in head and neck cancer

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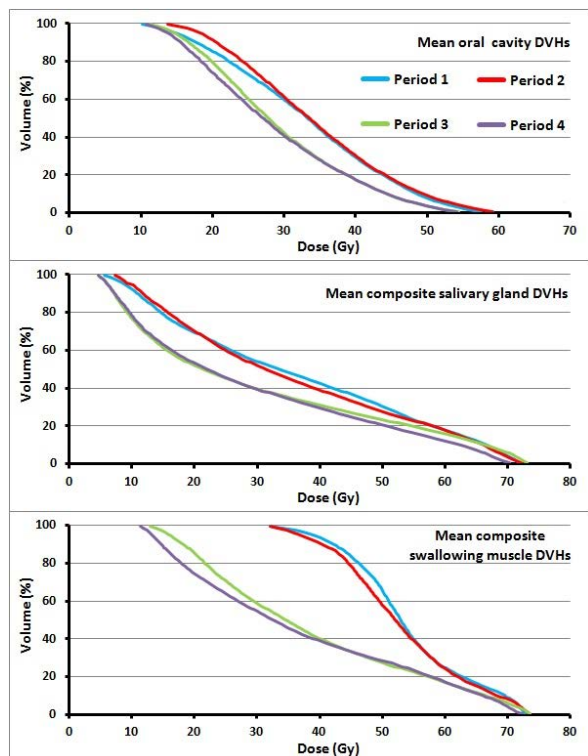
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**Purpose or Objective:** Advances in delivery techniques like intensity modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) facilitated increased treatment plan complexity, leading to the inclusion of more organs-at-risk (OARs) for sparing. Initial treatment planning

studies typically evaluate whether extra sparing affects boost/elective planning target volume (PTVB/PTVE) dose coverage or homogeneity, sparing of previously included OARs or dose conformity. However, once novel techniques are introduced in routine clinical practice, predicted changes are rarely retrospectively evaluated or confirmed. We therefore analyzed longitudinal changes in plan quality for head and neck cancer (HNC) patients treated at our department from 2005-2015 following the introduction of new technologies and planning techniques.

**Material and Methods:** 4x30 plans of oropharynx patients were selected from 4 distinct periods (P). P1: 7-field static IMRT plans with parotid gland sparing. P2: Dual arc VMAT plans including submandibular gland sparing. P3: VMAT with swallowing muscle sparing and further attempts to reduce parotid gland / oral cavity doses through manual interactivity during optimization. P4: VMAT with the same OARs as P3, but automatically optimized using in-house developed software. PTV prescribed doses were 54.25-57.75Gy in P1/P2, and 54.25Gy in P3/P4. 70Gy was prescribed to PTVB for all patients, delivered in 35 fractions as a simultaneous integrated boost. Plans were compared using mean dose to composite salivary glands (Dsal), swallowing muscles (Dswal) and oral cavity (Doc), PTVB/PTVE dose coverage (V95) and homogeneity indices (HI), and V5Gy (volume receiving 5Gy), V30Gy, V50Gy and mean dose to the body contour with PTV subtracted.

**Results:** The Figure shows mean salivary gland, swallowing muscle and oral cavity DVHs for each period and the Table summarizes the mean dosimetric results. OAR sparing, swallowing muscle sparing in particular (P1=55.0Gy to P4=38.6Gy), gradually improved throughout the periods without compromising PTV dose coverage, homogeneity or conformity indexes. In addition, P3 improved Dsal/Doc over P2 by 6.3/7.5Gy, illustrative of gains facilitated by improved planner experience and planning technique used. Automatically optimized plans (P4) achieved similar OAR sparing, Body-PTV doses and PTV V95/HI values as P3 plans. Although depending on the degree of OAR-PTV overlap, individual OAR sparing could vary between the periods, such differences are inherent to this type of study.



	Period	1 - Parotid gland sparing IMRT	2 - Salivary gland sparing VMAT	3 - Swallowing muscle sparing VMAT	4 - Automatically optimized VMAT
PTVB	V95 (%)	98.1 ± 1.6	98.8 ± 0.9	99.0 ± 0.5 *	98.9 ± 0.2 *
	HI (%)	9.8 ± 1.0	10.0 ± 1.4	10.4 ± 1.1 *	9.7 ± 0.9 #
PTVE	V95 (%)	98.5 ± 1.0	98.2 ± 1.0	97.7 ± 1.2 *	98.2 ± 0.6 #
	HI (%)	13.3 ± 2.1	13.6 ± 2.1	15.8 ± 2.2 * †	13.2 ± 1.4 #
Mean Dose (Gy)	Salivary Glands	41.1 ± 7.1	37.3 ± 7.7	31.0 ± 5.0 * †	31.3 ± 6.4 * †
	Swallowing muscles	55.0 ± 5.7	56.0 ± 8.0	40.8 ± 7.3 * †	38.6 ± 7.9 * †
	Oral cavity	35.3 ± 7.2	36.8 ± 8.2	29.3 ± 7.8 * †	27.5 ± 8.2 * †
	Mean Dose (Gy)	20.5 ± 2.1	20.6 ± 1.9	18.7 ± 1.2 * †	18.9 ± 1.6 * †
Body-PTV	V5Gy (%)	73.8 ± 5.9	79.1 ± 3.1 *	74.5 ± 3.8 †	73.5 ± 4.7 †
	V30Gy (%)	29.7 ± 4.8	29.6 ± 4.9	27.2 ± 2.8 * †	27.2 ± 3.6 * †
	V50Gy (%)	7.4 ± 2.4	7.0 ± 2.4	4.5 ± 0.8 * †	5.3 ± 1.5 * † #

\* , † , # : Statistically significant differences ( $p < 0.05$ ) with respect to period 1, 2 and 3, respectively ANOVA with post-hoc Bonferroni analysis

**Conclusion:** Successive improvements in radiotherapy technologies and planning techniques substantially improved HNC plan quality. Swallowing muscle sparing did not compromise sparing of other OARs, PTV dose coverage and homogeneity or dose deposition in the remainder of the body. On the contrary, salivary gland doses, HIB/HIE and Body-PTV doses generally decreased in P3/P4 compared to earlier periods.

#### PO-0844

**Dosimetrical advantages of 4D mid-vent: should every LA NSCLC patient be treated this way?**

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**Purpose or Objective:** In this study, we aimed to compare the effect of 4D mid-ventilation vs. free breathing 3D CT technique on target volume differences and corresponding dosimetrical changes using intensity modulated radiation therapy (IMRT) for patients with locally advanced non small cell lung cancer (NSCLC). Furthermore, additional investigation was performed to evaluate the possible dosimetrical improvement by using volumetric modulated arctherapy (VMAT) instead of IMRT.

**Material and Methods:** Twenty-three patients with locally advanced NSCLC were scanned with 4D-CT acquisition for treatment planning purpose. The different breathing phases were analyzed to obtain the tumor motion (direction and amplitude) and to determine which dataset better represents the mid-ventilation phase. Based on the gross tumor volume, two planning target volumes were generated for each patient: One using 15 mm margin in all three directions (PTV-3D) and the other with 12 mm with the margin of 1/4 of the movement (= mid-ventilation approach, PTV-4D). For objective comparison, IMRT plans (3D-IMRT, 4D-IMRT) were made by using Pinnacle v9.0 (Philips, Eindhoven, the Netherlands) with identical optimization parameters. For the 4D mid-vent, additional VMAT plan was generated. All DVH were collected using the VODCA package (Medical Software Solutions, Hagendorn, Switzerland). For the evaluation, the following dosimetric parameters were used: for corresponding PTV coverage using V95%, for lungs-PTV4D (for objective comparison of healthy lung volume) V20Gy and Dmean, for spinal cord Dmax, for oesophagus Dmean, while for heart V35Gy. All 4D plans were verified at the treatment machine following the institutions QA procedure. Differences were tested using the pairwise t-tests with the significance level of  $p < 0.05$ .

**Results:** Based on the 4D-CT analysis, the average (range) tumor motions were 3.1 (0-11.2) mm for cranio-caudal, 1.7 (0-4.6) mm for antero-posterior and 1.9 (0-4.0) mm for lateral direction. The average PTV volumes were reduced on average with 14% (Table 1).